§ 24. Simulation Study of Twisted Magnetic Loops

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A solar flare is one of the most interesting and important phenomena as an energy release event in the solar atmosphere. The released energy amounts to about 10^{25}J. Amo et al.[1], Ozaki et al.[2] and Takamaru et al.[3] have studied the behavior of the twisted magnetic flux tubes, which is modeled for the coronal magnetic field. According to their studies, the scenario of the solar flare is considered as follows. First, magnetic loops (loop-like magnetic flux tubes which are anchored at the photosphere) are twisted by the photospheric surface convection. The magnetic energy is stored in the twisted magnetic loops by the convection, and then converted to the kinetic and thermal energy through the magnetic reconnection process. Observed is such converted kinetic and thermal energy as the solar flare.

G.Haerendel have indicated a possibility that not a single magnetic loop but two or more magnetic loops are entangled in the way of the cascade in actual solar flares[private communication].

We developed the three-dimensional magnetohydrodynamic(MHD) simulation code which enables to pursue the complexed magnetic field configuration in more realistic plasma where the compressibility is taken into account. In this report, we show the simulation results for two initial magnetic field configuration; one is the case a single magnetic loop is twisted, and the other is two magnetic loops are twisted simultaneously.

Fig.1 and Fig.2 show the temporal evolutions of the magnetic field lines for the cases of 1) the single magnetic loop and 2) two magnetic loops, respectively. In the first case, the magnetic loop twisted by photospheric convection continues to expand merely. In contrast with the former case, two twisted magnetic loops collide with each other, and the magnetic reconnection occurs between them due to the attractive force of the current.

Fig.3 shows the temporal evolution of the conversion rate from magnetic energy to kinetic and thermal energy. The solid and dashed lines indicate the conversion rates of $(\boldsymbol{j} \times \boldsymbol{B}) \cdot \boldsymbol{v}$ [$\boldsymbol{j}$:current density $\boldsymbol{B}$:magnetic field $\boldsymbol{v}$:velocity] and Ohmic heating, respectively. Fig.3(a) shows that when a single magnetic loop is given initially, no drastic conversion is observed, which is the similar result given by Ozaki et. al., while in the second case shown in Fig. 3(b) the energy conversion is observed in the way of the burst when the magnetic reconnection occurs between magnetic loops.

In future, we will perform the simulation under the more realistic magnetic field configuration modeled the actual solar surface.

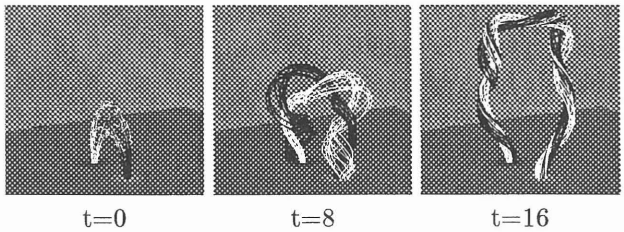

Fig. 1. Temporal evolution of the magnetic field lines for a magnetic loop. Black lines are magnetic field lines starting from the points located on one of the pole, white lines are those starting from the the other pole.

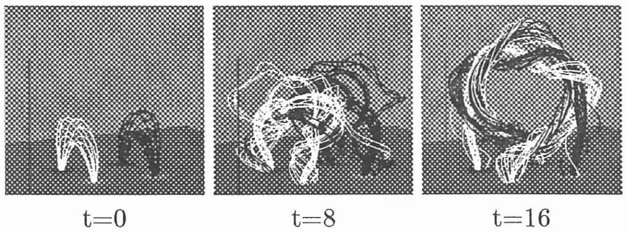

Fig. 2. Temporal evolution of the magnetic field lines for two magnetic loops. The magnetic loops are indicated in black and white lines.

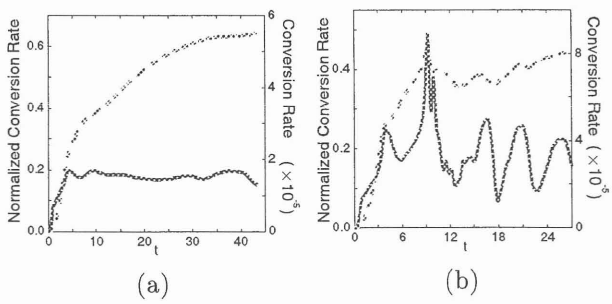

Fig. 3. The temporal evolutions of conversion rate of magnetic energy; the solid lines represents the rate of conversion by $(\boldsymbol{j} \times \boldsymbol{B}) \cdot \boldsymbol{v}$, and the dashed lines represent those of conversion by Ohmic heating.
, in the single magnetic loop case (left panel) and two magneticloops case (right panel).

References
1) H.Amo et al.,Phys.Rev.E 51(1995),5,A
2) M.Ozaki,T.Sato,ApJ. 418(1997)524
3) H.Takamaru,T.Sato , Phys.Plasmas,4(1997)8